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Methodology for the Selection of Cots Components in Small Satellite Projects and Short-Term Missions

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***Abstract*— *From a managerial point of view, considering budgets increasingly lean and controlled, besides a restricted schedule there is a need to find cheaper and more viable alternatives for the scenario presented with related to commercial electronics parts. On the other hand, the increasing offer of COTS (Commercial Off The Shelf) with the reached quality by manufacturers seems a good opportunity to use COTS components in electronic projects for small satellites with short and medium-term missions, through a coherent study that meets the restrictions mentioned above. For that, a method that helps in indicating the best COTS for the systems engineer and/or project engineering can be of great use.*

Keywords*— *COTS Quality; Failure rate, Small satellites; Short-term mission, Taking decision.

I. INTRODUCTION

The current trend in the use of Commercial-Off-The-Shelf (COTS) components, because of cost management, development time, availability for purchase beyond the quality levels achieved with the accelerated growth in the utilization in automotive electronics, and smart phone, sees an excellent opportunity for its use in short-term space projects.

On the other hand, COTS does not follow the rigor established in the military standards in terms of tests, selection, documentation, and quality levels reached, which makes it very difficult to trace the component in its manufacture and tests.

The great obstacle in the use of these components falls in the spatial case on the inhospitable environment to which they will be submitted.

In the space environment, some of the main factors that degrade the components are:

- Vibration (acceleration) at launch;
- Thermal (during the life cycle of the satellite);
- Ionizing radiation (total accumulated dose - TID and single-effect events - SEE's) from the trapped particle in radiation belt around of the Earth and solar activity; Therefore, the right choice of EEE components to be used in the design of satellite subsystems / equipment is of paramount importance.

Choosing the best COTS becomes a KEY OPERATION in terms of quality.

In this study, we considered the design of an equipment / subsystem. The COTS component to be used in the equipment performs a specific function according to the electrical functional requirement of the proposed circuit in a given electronic module as a solution to the desired functionality.

II. OBJECTIVE

This paper proposal aims to present a methodology for the selection of EEE COTS components in small satellites and short duration missions.

III. DEFINITION

Important definitions of COTS according to NASA [1]:

3.1 COTS: A component designed for applications in which only the manufacturer of the item or supplier establishes and controls the specifications for performance, configuration and reliability (including design, materials, processes and testing), without additional requirements imposed by external users and / or organizations. For example, any type of assembly or component through a catalog without any additional testing at the component level. Delivery of the component by the manufacturer as is.

3.2 COMPONENT SELECTION: Consists of a series of tests and inspections to remove non-conforming components and/or infant mortality (components with defects that are likely to result in initial failures) and thus increase the reliability of the components selected for use.

3.3 COMPONENT BURN IN TEST: Test applied to the electrically charged component (current or voltage) at an elevated temperature for a specified number of hours. It is an accelerated aging process and attempts to stress the component at a maximum rated value under operating conditions to reveal intrinsic at time failures and early defects (infant mortality: manufacturing defects).

3.4 COMPONENT CHARACTERIZATION: Process of testing a sample of components in an environmental range (temperature thresholds and acceleration levels) and applications to determine the ranges of key electrical parameter values that can be expected from all components produced of the type tested. Component characterization results are often used as a basis for establishing batch qualification tests.

3.5 COMPONENT SCREENING: A series of intended component-level tests and inspections to remove nonconformities and child mortality (defective components) and increase confidence in the component selected for use.

IV. CONTEXTUALIZATION

There are three main reasons for using COTS components in space projects:

- Best performance;
- The absence of list of parts qualified for space;
- 1/10 of the cost of QPL equivalent for space

The first two items are the main reasons for use in space projects, the lowest cost being the main driver for satellite launchers and constellations (http://wpo-altertechonology.com/accede) [2].

Given the possibility of using some options available in the market, but different manufacturers and unknown quality levels in terms of reliability, we propose to discuss the following approaches:

4.1 Develop a method of choice based on adaptations of issues from the reliability area to a failure probability approach;

4.2 Use the FIDES guide [3] to calculate component failure rate based on physical failure mechanisms (Overstress: thermal, mechanical, relative humidity, subassembly of plates and weld points) and manufacturers' quality factors (manufacturing processes and quality) considering the life stages of the component;

4.3 Show a path for choosing cost-based COTS in specific cases when the intended COTS in the project does not have sufficient data to prove or demonstrate the desired reliability through accelerated environmental testing for MTTF inferences and burn-in for the general cases (up screening).

V. METHODOLOGY

The selection of the appropriate COTS component is not a trivial task and was considered a decision-making process with several criteria. In our case, only two criteria: reliability and cost.

After allocating the reliability of the proposed electronic subsystems / modules, taking into account the minimum reliability established for the subsystem in question (our case study: power module - DC / DC converter), an analysis will be made using the FIDES method to find out the failure rate and a theoretical cost analysis related to the minimum tests necessary for screening in specific cases

VI. FORMULATION

We formulated the selection model considering the following challenges associated with the problem:

6.1 Complexity: Integration level for IC and Hybrid integrated circuits (analog and digital circuits and logic gate No.);

6.2 Costs: Additional Electrical / Environmental Functional Tests - Burn-in and HALT/MTOL [4];

6.3 Weighted quality level: (AHP or FIDES Guide [5]: manufacturer quality factors, features, and functionality preferences);

6.4 Operational profile: Mission time, Operating temperature, duty cycle and radiation exposure (tests and solutions knows to mitigation);

Note: Bold item involve additional costs and will be treated with a comparative cost analysis to MIL STD 883 or ECSS-Q-ST-60-13C class 3 [5]

VII. PROCEDURE FOR CHOSING

7.1 FMECA shall be done to indicate the critical parts that can take a crucial failures of the system/subsystem;

7.2 Calculate of the importance of reliability of each component (Birnbaum measure) based on the

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failure rate (λ) of an equivalent component MIL 883 (HDBK 217) [6].

7.3 Mapping of less critical components after the considerations earlier done;

7.4 Using the FIDES Guide to determine the failure rate by treating the physical failure mechanism besides the Karmiol / Bracha Method (adapted) with focus on the complexity the most important effect from the effects factors listed below, once that it will be treated of analogous way to component level:

- 7.4.1 Operating time / duty cycle
- 7.4.2 Operating Profile (Temperature Range)
- 7.4.3 Component complexity;

7.5 Optimization method [7] based on two criteria: Reliability and Cost (testing), aiming at up-screening having reference to MIL 883 or ECSS-Q-ST-60-13 C class 3;

7.6 Decision making of proposed COTS components based on data obtained from manufacturers audit by questions formulated in FIDES Method and expert opinion (using the AHP or WSM method).

Note: The FIDES Guide deals with manufacturer quality factors (Π_PM and Π_Process) together with the AHP method can be treated with the designers the preference functional of the component.

VIII. APPROACHES TO ITS SOLUTION

In order to begin the discussion around the problem of choosing the appropriate COTS to meet the electrical and environmental functional requirements required in the project, we must stick to the sequence of steps necessary to achieve our goal starting with the allocation of reliability for each unit or subsystem of the mini-satellite so that the mission achieves its goal.

A reliability allocation study must have been done previously at the subsystem/equipment/ module level before we can start choosing the COTS component to use.

Schematic diagrams of the problem and solution are shown in Figures 1, 2 and 3 as follow:

Propose Solution:

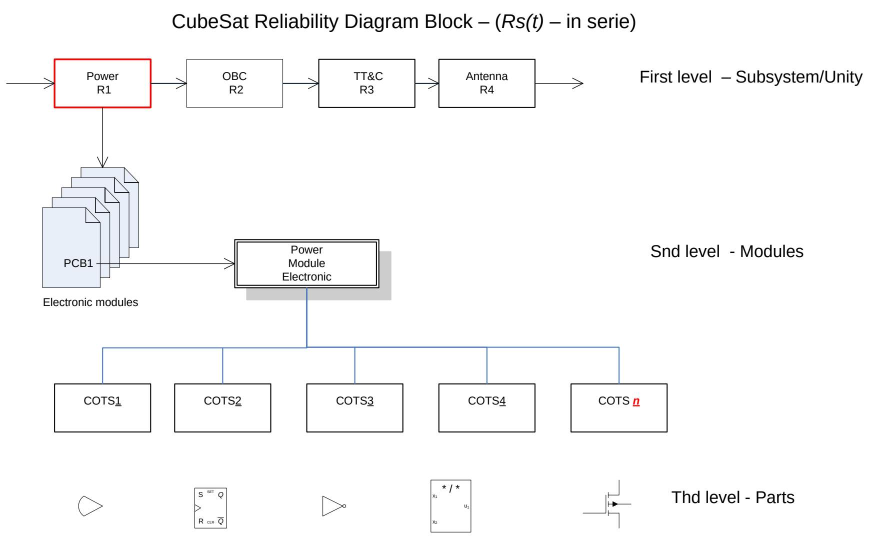

Fig 1: COTS to be used

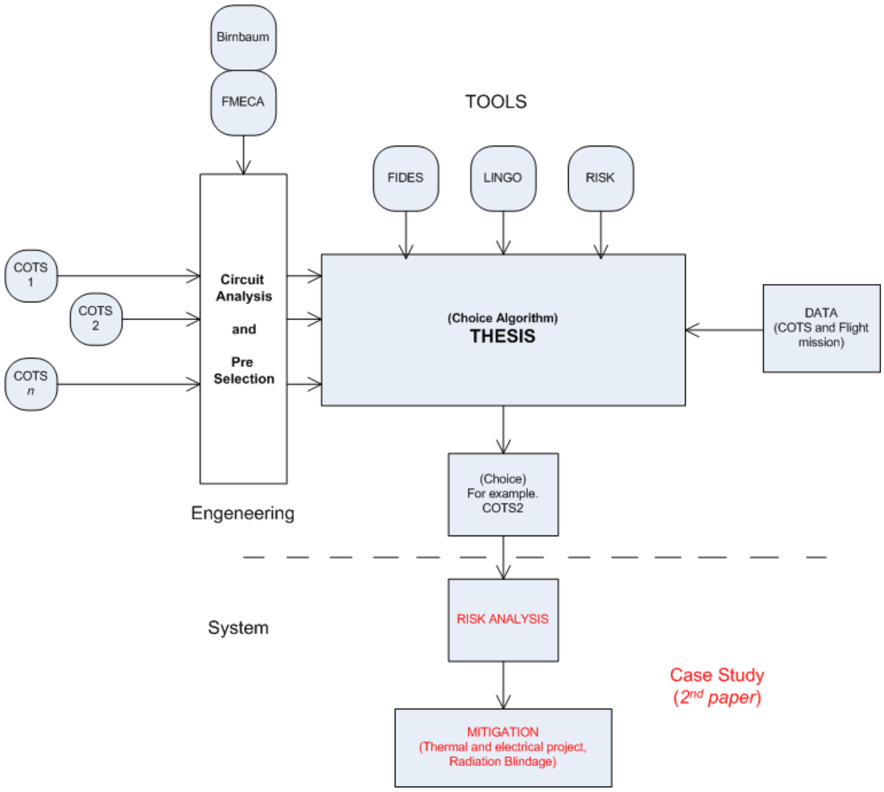

Fig 2: Methodology for choosing COTS

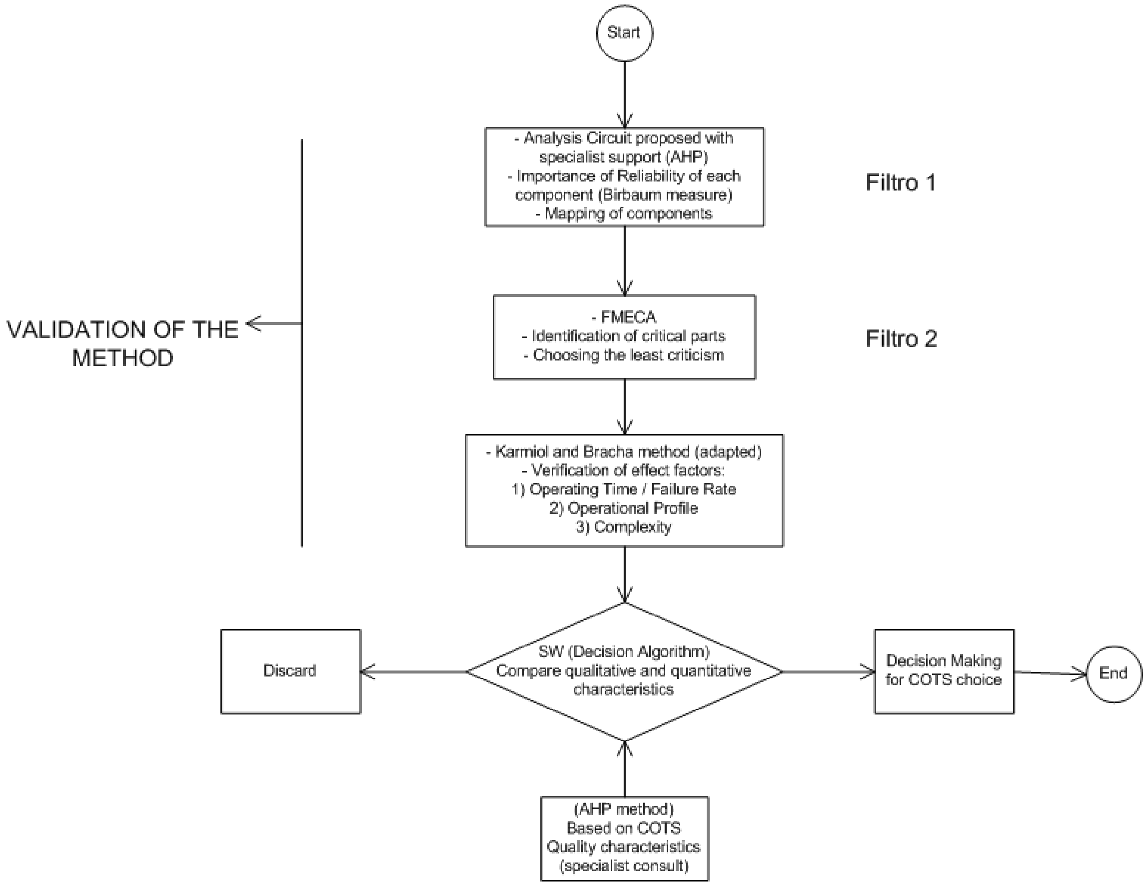

Fig 3: Flowchart COTS Algorithm of Choice

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Once we have the number or figure of reliability of the subsystem under study we will treat on the suggested procedure.

We use the reliability allocation method called the AGREE method which is based on the complexity of the unit or subsystem rather than the failure rate. The importance or essentiality of the unit quantitatively defines the relationship between the unit and the target system failure rate and is explicitly considered in the AGREE allocation formula.

The allocation formula is used to determine the minimum acceptable average time of each unit to satisfy the minimum acceptable system reliability. The premise is that the unit within the system has an independent failure rate and operates in series with respect to its effects on mission success.

Unit complexity is defined in terms of the number of modules and associated circuits where a module can be a valve, a transistor or a magnetic amplifier. The unit importance factor is defined as the probability of system / unit failure if a particular unit fails. If the factor of the importance of a unit is 1 the unit must operate satisfactorily for the system to operate satisfactorily otherwise if the factor of 0 then the failure of the considered unit does not interfere with satisfactory system operation.

The specific basis of allocation is to require each module to make an equal contribution to the success of the mission and the equivalent requirement would be for each module to have the same expected average life or failure rate.

The mathematical model for the method considering the approximation:

$$e^{-x} = 1 - x \quad (1)$$

Where:

x is a small and less than 1

The allocated failure rate of this unit is shown in AGREE.

$$\lambda_j = \frac{n_j[-\log_e R^*(T)]}{NE_J t_j} \quad (2)$$

Where:

nj = number of modules (module = electronic component) of subsystem / unit, jth;

N = total number of components in the system;

E_J = Importance factor of jth unit,

and

tj = number of hours the jth unit will be required to operate in T system hours (mission time) (0 <tj (duty cycle) ≤ T)

The allocated reliability for the jth unit (subsystem) for tj (duty cycle) unit operating hours, R (tj), is given by

$$R(tj) = 1 - \frac{1-[R(T)]^{nj/N}}{Ej} \quad (3)$$

IX. BIRNBAUM MEASURE

The importance of a component should depend on two factors [8]:

9.1 The location of the component in the PCA / Unit; here we are concerned with a good thermal design in order to reduce thermal stress, understanding that temperature is one of the main factors for component reliability;

9.2 The reliability of the component in question.

Birnbaum (1969) proposed the following measure of reliability importance of a component

Birnbaum's measure of the importance of a component i at time t is:

$$I^B(i/t) = \frac{\partial h(p(t)}{\partial pi(t)} \quad (4)$$

Birbaum's measurement is then obtained from the partial differentiation of system reliability with respect to pi (t). This approach is well known as a classical sensitivity analysis. If $I^B(i/t)$ is large, a small change in component reliability will result in a large variation in system reliability over time. Let's consider each independent component for analysis, this means that there is no independence between components (obviously this approach does not reflect the actual behavior of systems, this is the interdependence between modules or series components) but already points to a degree of importance. reasonable in its determination.

By noting the fault tree, Birnbaum's measurement [9] can be rewritten:

$$I^B(i/t) = \frac{\partial Q0(t)}{\partial qi(t)} \quad (5)$$

Where:

qi (t) = 1-pi (t)

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$$Q0(t) = 1 - ps(t) = 1 - h(p(t))$$

Birnbaum's measure is named after the Hungarian-American professor Zygmund William Birnbaum (1903-2000)

Thus, the next step in this methodology would be the search for options for DC/DC converters in the component market that would meet the functional electrical and environmental requirements of the project. For this, we need to find out a failure rate related to DC/DC Converter prescribed and to check if that value is appropriated in our case it means if the value not compromised the reliability allocated for the unit. Otherwise, it continues to choose another part that meets this requirement.

X. FAILURE SURVEY OF COTS [FIDES GUIDES]

Reliability Prediction Using the FIDES 2009 Guide.

The FIDES evaluation model proposes a reliability prediction with constant failure rates. Therefore, the probability of failure is independent of the number of hours of a component in operation. This means that only random failures during the life of a component are considered and early failures (infant mortality) and wear failures are not included.

This methodology for reliability evaluation in electronic components has two components:

- Component reliability prediction guide,
- Reliability process control and audit guide.

Although component prediction models allow component failure rates to be calculated based on component characteristics and application-related data (eg, applied thermal and electrical stress), the reliability process control and audit guide assess component manufacturing quality and the effects of all processes throughout the life cycle from the design specification phase to maintenance and support activities. The FIDES Guide aims to enable a realistic assessment of the reliability of electronic equipment, including systems operating in harsh environments (defense systems, aeronautics, industrial electronics, transportation, etc.). The general model of FIDES is expressed by the equation:

$$\lambda = \lambda_{Physical} * \Pi_{PM} * \Pi_{Process} \qquad (6)$$

In this case, our components for study: a DC / DC converter (hybrid), A / D Converter (IC) and a semiconductor we apply to formulas to find the failure rate, as follows:

Hybrid

$$\lambda_{Physical} = \sum_i^{Phases} \left(\frac{t_{annual}}{8760}\right)_i * \left[\left(\lambda_{0TH-TCy} * \left({}^{\gamma}{}_{TH} * \Pi_{TH} + {}^{\gamma}{}_{TCy} * \Pi_{TCy}\right) + \lambda_{0M-RH} * \left({}^{\gamma}{}_{M} * \Pi_{M} + {}^{\gamma}{}_{RH} * \Pi_{RH}\right)\right] * \left(\Pi_{Induced}\right)_i \qquad (7)$$

Integrated Circuit and Semiconductor

$$\lambda_{Physical} = \sum_i^{Phases} \left(\frac{t_{annual}}{8760}\right)_i * \left[\left(\lambda_{0TH} * \Pi_{TH} + \lambda_{0TCyCase} * \Pi_{TCyCase} + \lambda_{0TCySolderjoints} * \Pi_{TCySolderjoints} + \lambda_{0RH} * \Pi_{RH} + \lambda_{0Mech} * \Pi_{Mech}\right)\right] * \left(\Pi_{Induced}\right)_i \qquad (8)$$

Nota: All factors (sensitivity, location, technological, physical stress) and basic failure rate associated with the assembly will be requested in the algorithm of choice. The $\Pi_{PM} * \Pi_{Process}$ parameters are quality factors of the manufacturer and of the component and are calculated based on evaluations and audits at the manufacturer when is possible, if not, we use default values suggested by FIDES.

XI. COMPLEXITY FACTOR

We will make an analogy with the Karmiol / Bracha [9] (the method used to determine effects factor weights to obtain unreliability and subsequently allocate reliability to subsystem/unit) with the complexity of a component understanding that the problem handling can be analogous. We introduce this factor to increase the stiffness in the reliability calculation since we cannot be increased reliability in the usual ways as a redundancy. In fact, the idea is to increase unreliability by the fact to be COTS

Karmiol/Bracha(adapted) considers four effect factors, namely:

a) Sublevel Complexity;
b) Operating time;
c) Operational profile;
d) Criticality and State of art

Understanding that items b, c, d are somehow already covered in the physical failure rate model through the failure mechanisms addressed by the FIDES method, we focus our efforts on **complexity**.

$$C = 1 - e^{-K_b + 0.6kp} \qquad (9)$$

Where:

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Kb and Kp should be estimated at the beginning of the development stage.

$$Kb_i = 10\ n_{bi}/n_{bc}$$

nbi = Number of components at sub level i;

nbc = Number of components in the most complex sub level

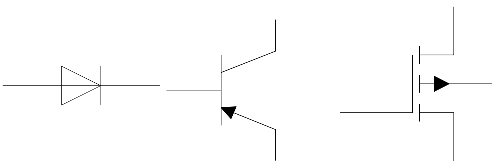
*Kp = Number of redundant components

*The Kp factor will not be used because the component functionality internal is not being redundant. We understand that the complexity of the component is associated with the levels of integration of the various functions performed by the component, for instance, hybrids and microcircuits.

So the complexity factor is:

$$C = (1 - e^{-K_b})$$

Therefore, for a semiconductor type, we have for example:



Bipolar, Transistor and Mosfet

Fig 4: Semiconductor Schematic Symbols

Kb=10
C = (1- 0.00004539993)
C= 0.9999540007

In other words, the complexity of the component in this case is low and therefore coherent with the semiconductor diode component. By the other hand component more complex tends to zero.

Low Complexity= 1

High Complexity≈ 0

For an integrated circuit, we have:

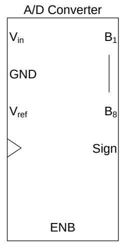


Fig 5: (MAX1112) [10]

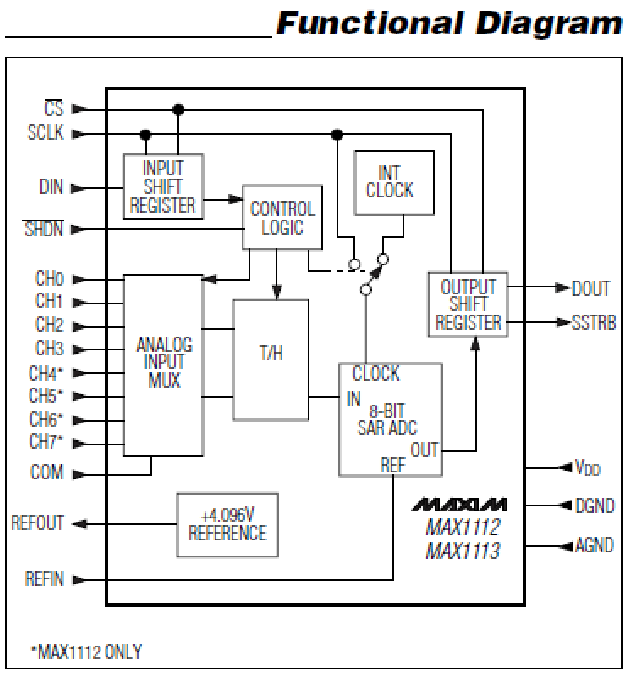


Fig 6: Ex.: Schematic symbol of an A / D converter

Kb=10

nbi = 8 [n. of elements at sub level i (functional blocks)]

Active Components:

Input Shift Register, Output Shifter Register, Logic Control, I / O Multiplexer, Voltage Reference, 8-bit A / D Converter, Clock Generator, T / H,

Passive Component:

Analog switch

nbc = 300 [number of elements (discrete components) in sub-level most complex]

$\mathrm{Kb_i} = 10\ \mathrm{n_{bi}/n_{bc}}$

$\mathrm{Kb_i} = 10(8/300)$

kbi = 0.26

$\mathrm{C} = (1 - \mathrm{e}^{-\mathrm{K_b}})$

$\mathrm{C} = (1 - \mathrm{e}^{-0.26})$

$\mathrm{C} = 0.23$

For a Hybrid type circuit (DC / DC Converter) we have:

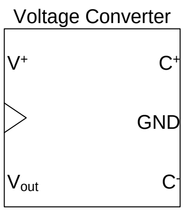


Fig 7: Ex.: DC / DC Converter Block

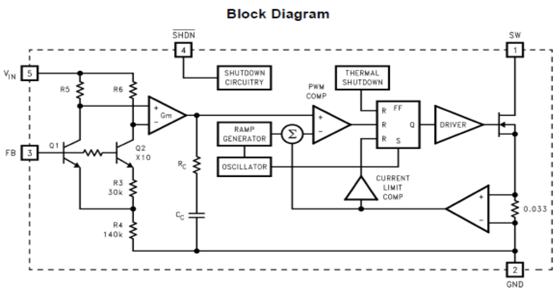


Fig 8: Block diagram of the DC / DC Converter (LM2731) [11]

$\mathrm{C} = (1 - \mathrm{e}^{-\mathrm{K_b}})$

Kb = 10

nbi = 22 (n. of elements in 1st level)

Active Components:

Comparator, PWM, FF (RS), Oscillator, Adder, Ramp Generator, Current Limiter, Shutdown Circuit, Driver, Transistors and FET

Passive Components:

Resistors and Capacitor

nbc = 148

Kbi = 10 nbi / nbc

Kbi = 10 (22/148)

Kbi = 1.4

$\mathrm{C} = (1 - \mathrm{e}^{-\mathrm{K_b}})$

C = 0.75

After we have been able to determine a failure rate for the COTS via the FIDES method we multiply the result by C (complexity factor) and close the loop in the choice algorithm to see if the value still meets the allocated reliability for the module/circuit in question (one mix between two methods FIDES and HDKB 217). Another thing that must be observed in the case of less complex digital components is that the number of gates will be used as a stiffness factor in the failure rate. Otherwise, we start with a new choice from the available manufacturers. If not apply additional tests like Burn-in or (HALT or MTOL) for MTTF inference and cost analysis, optimizing Reliability versus Cost and having as a reference to MIL 883 or ECSS-Q-ST-60 -13C Class 3

The decision making in choosing the COTS would then be after the analysis of the component failure rate via FIDES Guide and its consistency with a decision based on functional component preferences by the designer through an analysis via AHP and the listed criteria.

XII. COTS RADIATION

Considering the cost of testing in a qualified laboratory in the order of USD1500 per hour and minimum test time required of 60 hours, one can have an idea of the final cost of one of these non-destructive tests since one would be curious to see the functional behavior (some electrical parameters) of a specific component under radiation levels that must be found in the environment provided for in the mission based on Software such as SPENVIS of ESA, OMERE and ANGEL [12]

Some radiation of the type TID, SEU and SET can be mitigated by means of some known solutions, such as:

12.1 Physics: - Metallic shield (Titanium sheet);

12.2 Better Physical Positioning of the radiation sensitive (critical) electronic module inside the satellite (small satellites) - Software: GEANT 4, TRAD'S and FASTRAD [13];

12.3 Coding: EDAC, Watchdog Timers, TMR and HDL

XIII. ENVIRONMENTAL TESTS FOR SPECIFIC COTS

We will start by treating Burn-in tests as the main test for the elimination of defective components (infant mortality), understanding that eliminating the components that may have manufacturing defects, the rest according to the bathtub curve (failure rate versus time curve).) remains constant with constant failure rate during its "useful life" and "wear" at the end of the project's useful life.

It is understood that the rate of thermal variation predicted in the Burn-in tests (cycle: hot ↔ cold) will induce the mechanisms of physical failure of the component in addition to an acceleration in the aging of the component.

Additional accelerated thermal tests in order to verify the MTTF and estimate a batch failure rate will also be carried out and inspections based and adapted according to the reference

ECSS-Q-ST-60-13C Class 3

XIV. COST ANALYSIS

All of these tests generate costs so a balanced cost analysis of the type of optimization will be necessary and a risk analysis associated with the problem will be implemented.

Total cost of a Burn in test:

$$C = Ax + L[(1 - R(X)] \quad (10)$$

Where:

A: is the cost of Burn in per unit time
L: is the cost of a failure during Burn in
R (X) = Distribution curve Probability of Failure (eg: Weibull) [17]

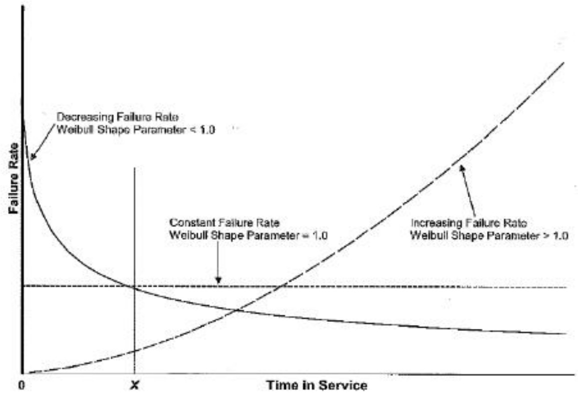


Fig 9: Failure rate characteristic

Table 01. ECSS-Q-ST-60-13 (today) applicable for active EEE

	Class 1	Class 2	Class 3
Evaluation	Complete	Complete	Partial
Justification	data collection	data collection	data collection
Screening	Complete	Partial	Light
Lot test	Complete	Complete	Partial

Summary of tests and inspections to be applied in the COTS:

14.1 Incoming inspection: date code, dimensional and visual characteristics (oxidation of leads and visual aspect of the encapsulation);

14.2 Specific Electrical Tests (digital and analogic);

14.3 PIND and Hermeticity test (if applicable);

14.4 Burn in and HAST test (special cases);

14.5 Documentary verification (manufacturer data collection)

XV. RISK ANALYSIS

This paper proposal aims to present a methodology for the selection of EEE COTS components in small satellites and short duration missions.

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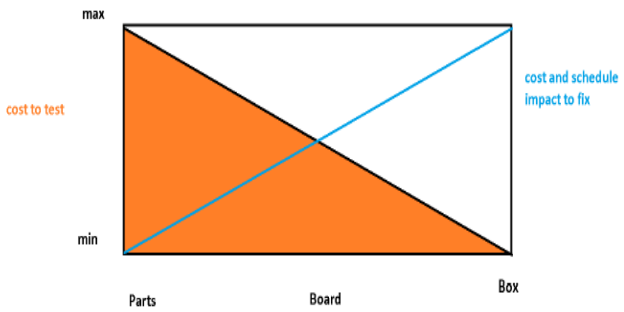

Fig 10: Notion of cost / schedule and its impacts by developing tests at the level of Components, Cards (PCA) and Boxes [14]

Figure 10 shows in the simplified representation that the cost to test decreases while the impact on cost and schedule for correction increases as component, board, and box level testing is performed. This occurs in component because the number of independent tests required decreases when moving to a higher level of testing. The cost of testing may be lower, but the cost and schedule consequences of a failure occurring increase dramatically. Total cost is lower if no problem or failure is detected at higher levels of testing.

We conclude that testing is important for minimizing future impacts and consequences. Therefore, there is a need to find a compromise or to measure and quantify the necessary tests in order to have a reasonable level of confidence for decision making when choosing the COTS to be used.

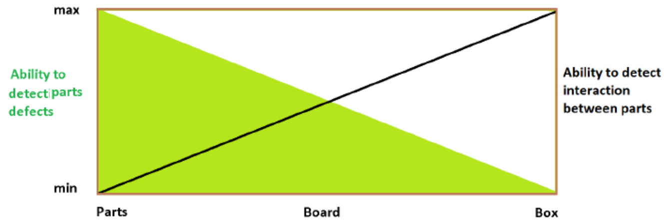

Fig 11: Notion of ability to detect defects in components and Interaction between components when developing tests at the level of components, PCA and Box

Figure 11, in a simplified representation, shows that testing at lower levels of integration improves the ability to detect component defects. Many partial defects are masked at higher levels of integration, but identifying these defects will increase system reliability, reducing the likelihood of latent failures. On the other hand, testing at higher levels of integration is more effective at detecting interactions between component manufacturing and assembly defects that affect reliability.

XVI. DECISION MAKING

As mentioned earlier AHP method [15] can be useful to decision making in the choice of COTS by experts

The following is an AHP model for choosing the COTS according to the listed criteria:

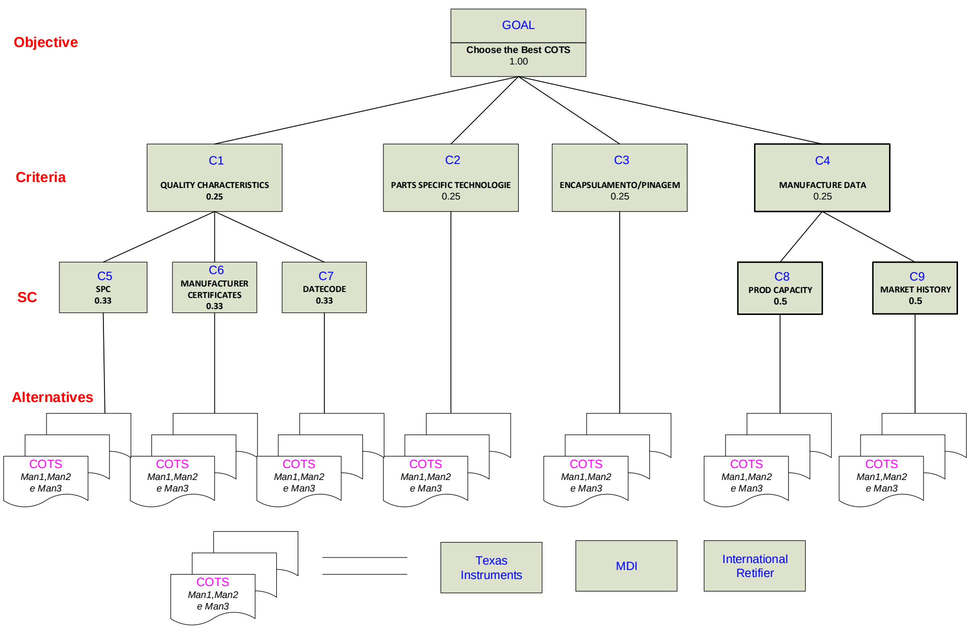

Fig 12: AHP structure model for choosing COTS

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XVII. CONCLUSION

This methodology approach is a convenient way to express the system reliability as a function of component reliability and the independence structure between the functional levels considered (subsystem/equipment/module/component) of course there is an interaction among level but in this study, the values were negligible. Another important point that must be appointed is about the making decision under many uncertainties considered in this model. By the other hand, these ways suggested give us a possibility to find out the best solution to the designers in the utilization of COTS in an electronic circuit searching a balance among Cost, Reliability, and Risk

XVIII. CASE STUDY:

According to the article [16], we have a graph where it is observed that the power subsystem presents a number of failures very significant.

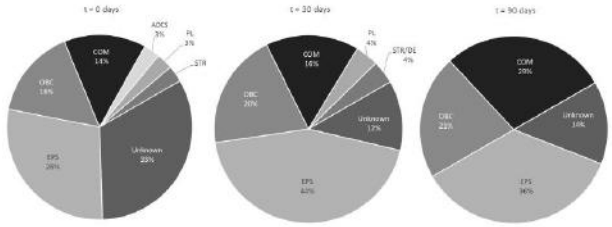

Fig 13: Faults observed in the subsystems in Cubes Satellites after injection in orbit, (Dead On Arrival), 30 and 90 days.

Based on this, we will perform an analysis in the power circuit of the Tancredo I Satellite "Tubesat" as a case study according to the proposed method for its validation considering in this case only 3 steps, as follow:

Consideration of the importance of reliability of each component (Birnbaum measure) based on the failure rate (λ) of an equivalent component MIL 883 or commercial by (HDBK-217).

Mapping of less critical components;

Using the FIDES Guide to determine the failure rate λ by treating the failure physics plus the Karmiol / Bracha Method (adapted) considering the complexity of the component according to the effect factors:

Procedure step by step:

18.1 Importance of Reliability

Table 02. Importance of the reliability of each component based on the failure rate (λ) HDBK-217 [17]

Digi-Key Part Number	Manufacturer Part Number	Desrição do Componente	Ref.	Categoria	Qtd	Taxa de falha - (λ) 1 Falha/10^6h	%
709-1279-1-ND	501R18W221KV4E	Cap.Ceramic SM 220pF 1206	C1	Capacitor	1	0.00387	1,230
1276-3047-1-ND	CL31A226KAHNNNE	Cap. Ceramic SM 22uF 1206	C4	Capacitor	1	0.00396	1,260
399-5507-1-ND	C1206C475K5PACTU	Cap.Ceramic SM 4.7uF 1206	C2,C5,C6	Capacitor	3	0.02085	6,642
478-3351-1-ND	08055C104MAT2A	Cap.Ceramic SM 0.1uF 0805	C7	Capacitor		0.04032	12,887
1276-1068-6-ND	CL31B105KBHNNNE	Cap.Ceramic SM 1uF 1206	C8, C9	Capacitor	2	0.04788	15,304
478-3351-1-ND	08055C104MAT2A	Cap. Ceramic SM 0.1uF 0805	C10	Capacitor		0.027	8,630
CRS06QMCT-ND	CRS06(TE85L,Q,M)	Diode CRS 06 SCHOTTKY 1A	D1 a D9	Diode	9	0.0088	2,813
B82462G4103M Farnell	B82462G4103M000 EPCOS	10 uH Inductor 10 X10	L1	Indutor	1	0.00092	0,294
311-1.5ARCT-ND	RC0805JR-071R5L	Resistor, 0805 1R5 Ohm	R1 a R8	Resistor	8	0.0035	1,119
311-470KERCT-ND	RC1206JR-07470KL	Resistor,1206 470 KOhm	R9	Resistor	1	0.001732	0,554
311-27KERCT-ND	RC1206JR-0727KL	Resistor,1206 27 KOhm	R10	Resistor	1	0.001575	0,503
311-12KERCT-ND	RC1206JR-0712KL	Resistor,1206 12KOhm	R12	Resistor	1	0.001575	0,503
311-47KERCT-ND	RC1206JR-0747KL	Resistor,1206 47KOhm	R13	Resistor	1	0.001575	0,503
311-180KERTR-ND	RC1206JR-07180KL	Resistor,1206 180KOhm	R16	Resistor	1	0.001732	0,554
311-100CRCT-ND	RC0805FR-07100RL	Resistor, 0805 100 Ohm	R20	Resistor	1	0.001575	0,503
MAX9929FAUA+-ND	MAX9929FAUA+	CI MAX9929FAUA Current SENSE AMP	U1 a U8	Current Sense	8	0.0581	18,570
LT3021ES8#TRPBFCT-ND	LT3021ES8#TRPBF	CI LT3021 V REG, LDO ADJ	U9	Regulador	1	0.0581	18,570
LM2731XMF/NOPBCT-ND	LM2731XMF/NOPB	CI LM2731XMF BOOST CONV, 0.6/1MHZ	U11	Conversor DCDC	1	0.02	6,395
MAX1112EAP+-ND	MAX1112EAP+	MAX1112EAP	U12	Conversor A/D	1	0.0098	3,132
				λp da Placa	∑ =	0.312864	

18.2 Mapping of less critical components

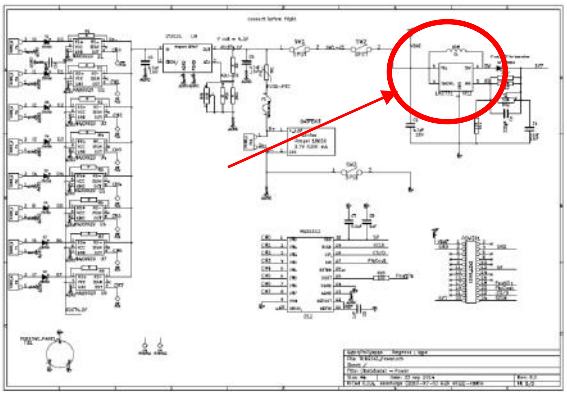

Fig 14: Electrical Scheme of the main power circuit of "Ubatubasat" [18].File TUBESAT_Power.sch

For instance: U11 – DC/DC Converter could be the component of interest for the choice of a COTS considering some aspects related to its importance in the circuit in terms of sensitivity in the reliability of the power subsystem, since it is sensitive but not as much as the voltage regulator, some ceramic capacitors and current sensors as shown in table 4.

18.3 The next step (FIDES Guides) in this methodology would be the search for options for DC/DC converters in the component market that would meet the functional electrical and environmental requirements of the project. For that, it is necessary to find a failure rate of the DC / DC converter and multiply by complexity factor in accord to suggest procedure and check if this value is appropriate in our case which means verifying that the value has not compromised the reliability allocated to the unit. In other wise, it continues to find another part that meets this requirement.

Calculation of the failure rate of the DC/DC converter using FIDES guide through the physical failure mechanisms:

Failure Rate = λPhysical* πpm* πprocess

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Input data:

λPhys: Failure rate calculated according to the physical failure mechanisms, phases and times considered.

Value = 379.59366

Πpm: Considers the factors of the component manufacturer's quality and component reliability in addition to a coefficient of the relationship between the representative (seller) and the manufacturer.

Value = 1.42262

Πprocess**:** Considers the audit done in the fabrication process at the company when possible if not use the default value suggests by FIDES although the precision is reduced.

Value = 4.75525

Output data:

Part Failure Rate = 2567.9183

(2567.9183x 10-9 or 2.567 x 10-6)

For a Hybrid type circuit (DC / DC Converter) we have:

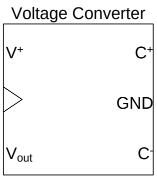

Fig 15: Ex.: DC / DC Converter Block

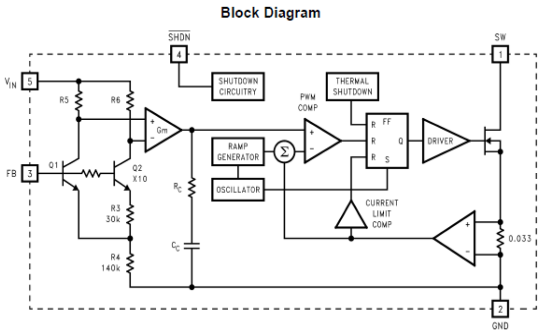

Fig.8: Block diagram of the DC / DC Converter (LM2731)

$C = (1 - e^{-K_{bi}})$

Kb = 10

nbi = 22 (n. of elements in 1st level)

Active Components:

Comparator, PWM, FF (RS), Oscillator, Adder, Ramp Generator, Current Limiter, Shutdown Circuit, Driver, Transistors and FET

Passive Components:

Resistor and Capacitor

nbc = 148
Kbi = 10 nbi / nbc
Kbi = 10 (22/148)
Kbi = 1.4

$C = (1 - e^{-K_{bi}})$

C = 0.75

Therefore, in accord to proposal of this paper, we have:

Failure Rate = FR/C

FR = 2.567/0.75

FR = 3.42 FITs ($1/10^6$)

For instance: Tancredo-I (Tube Sat)

Table 03. Reliability Allocated

System: (Payload) Langmuir Probe – (Ubatubasat) Primary Mission: Medição de Plasma Reliability requirement: R*(8760 hr) = 0.9				
Subsystem	**Number of parts, *nj***	**Operating time, hr, *tj***	**Essenciality, *Ej***	**Allocated reliability, *Ri*(*tj*)**
Power	81	8760	1	0.95
Transmissor/Receptor	46	8760	1	0.97
Controller	48	8760	1	0.97
Antenna	7	8760	1	0.97
	N = 182	8760	1	0.99

So, for the Tancredo I (Tubesat) power subsystem, we have:

nj = 81
N = 182
EJ = 1
tj = 8760hr

For the power subsystem, the reliability rate allocated considering reliability for the whole system of R (t) = 0.9, we would have:

$$R_1(8760tj) = 1 - \frac{1 - (0.9)^{81/182}}{1.0}$$

$$R_1(8760tj) = 0.95$$

N = total system components

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(1/2) Power PCA Rate failure $\lambda = 0.32$ change to

$\lambda = 3.74$ after calculate failure rate to DC/DC Converter suggested

$P(t{=}8760h) = 1 - e^{-\lambda t} = 1 - e^{-(3.74*10^{-6}\,x\,8760)}$

$P(t{=}8760h) = 1 - e^{-0{,}029}$

P (t = 8760h) = 0.029, that is, the DC / DC converter has around 3% probability of failing up to 8760h (one year) of use considering only one of the power cards (1/2). So it would serve this mission well, as the reliability allocated to the power unit was 95%.

Therefore, can we see that after a new failure rate calculated not have great impact in reliability allocated to power supplier. In this case, the DC/DC Converter found to power supplier PCA will met the reliability requirement established to mission time duration so it could be used

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